

# Marine protected areas for the snow crab bottom fishery off Kyoto Prefecture, Japan

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## 1. INTRODUCTION

Kyoto Prefecture is located on the northern side of central Japan and has about 320 km of coastline facing the Sea of Japan (Figure 1). There are many coastal and near-shore fisheries in the region, including set net (for sardine, yellowtail, red sea bream and squid), pole and line or long line (for red sea bream, bastard halibut, black rockfish and squid), gill net (for flat fish, prawn, blue crab and yellowtail), gathering and collecting (for abalone, turban shell and sea mustard [*wakame*]) and aquaculture (of yellowtail, red sea bream, bastard halibut and oysters and pearls). There are also offshore fisheries, such as purse seine (for sardines, horse mackerel and mackerel) and bottom trawling (for snow crab, brown sole, deep-sea smelt and northern shrimp).

This chapter focuses on management of Kyoto's offshore bottom trawl fishery. In 2005, bottom trawling was the second largest fishery sector in Kyoto prefecture. With fifteen vessels and six or seven crew members on each vessel, the trawlers harvested 437 tonnes of fish valued at US\$3.4 million (National Federation of Bottom Trawlers' Unions, 2006). (An exchange rate of 118 Japanese yen per US\$, the rate in March 2007, is used throughout this chapter.) The most important species for this fishery is snow crab (*Chionoecetes opilio*). Because of overfishing, catches of snow crab in the region declined dramatically, from 369 t in 1964 to 58 t in 1980. In an effort to restore snow crab stocks and generate more value, the organization of local fishers introduced various management measures. Specifically, a combination of permanent and seasonal marine protected areas (MPAs) were introduced as marine reserves or no-take zones and have been expanded since 1983. Permanent MPAs are meant to provide sanctuaries for snow crabs from fishing and were established around the snow crab's critical habitats. Seasonal MPAs are aimed mainly at avoiding bycatches of low-value crabs. Kyoto prefecture government supported these activities with funding and scientific research and advice. As a result, landing volumes increased from 58 t in 1980 to 195 t in 1999 and the total value produced rose from \$914 500 in 1980 to \$3 578 000 in 2001 (National Federation of Bottom Trawlers' Unions, 2006).

FIGURE 1  
Map of Japan and Kyoto prefecture



## 2. DESCRIPTION AND HISTORY OF SNOW CRAB FISHERIES

### 2.1 History of the bottom trawler fishery in Kyoto

Exploitation of snow crab in Kyoto dates back several hundred years. Local records indicate that seine fishing from hand-powered boats started in the area around the end of the Heian era (mid-twelfth century). In the 14th through the 16th century, seine fishing targeted sea bream, smelt, goosfish, goatfish and flat fish. In the Meiji era (the late 19th century), the fishing grounds off Kyoto were expanded to about ten nautical miles from the coast and provided flat fish, deep-sea smelt, cod and snow crab (Kyoto Bottom Trawlers' Union, 1994). In 1919, powered vessels were introduced in the area. Vessel size and engine power increased rapidly, as did the area fished by these vessels. This increase in capacity and area fished led to conflicts among various groups of fishers. All fishers were members of a local fisheries cooperative association (FCA), but the FCA could not respond to the dramatic change in fishery technology. Overcapacity became a chronic problem for Kyoto's bottom trawler industry.

To address the overcapacity, the central government introduced a boat licensing system for bottom trawling in 1922. The government also prohibited bottom trawling in near-shore grounds to avoid inter-gear conflicts. However, the licence system failed to reduce capacity and bottom trawling vessels continued to grow in size and number. By 1930, bottom trawlers were landing more than one-fourth of the total fish harvested in Kyoto, which intensified the conflicts with other fisheries. Because of this continuing and intensifying conflict, the central government introduced a 60 percent capacity-reduction plan for Kyoto's bottom-trawling vessels in 1937. The plan proved to be effective – fishing capacity dropped dramatically after its introduction.

The restrictions on bottom trawler fishing were temporarily relaxed when World War II began in 1941. The central government wanted to enhance food production and secure its supply. Bottom trawler production reached a record high of 3 887 t in 1942. The Kyoto Bottom Trawlers' Union was founded in 1944 to further increase bottom trawlers' harvests. An organization that today is responsible for conservatory fishery management was originally established to further exploit the resource. The union is composed of local bottom-trawling fishers and has played the central role in fisheries governance in the area. Today, there are fifteen bottom-trawler vessels operating in Kyoto, all members of the union. They operate along the 200–350 metre contour, targeting snow crab, brown sole, deep-sea smelt and northern shrimp (Photo 1).

### 2.2 Ecology of the snow crab

Snow crabs (Photo 2) spawn between early February and late April with a peak in March. After three larval stages, larvae settle to the bottom and metamorphose into the first benthic stage in June (Kon, Adachi and Suzuki, 2003). They moult repeatedly as they mature in September and October. Female crabs moult eleven times over the course of seven or eight years and are mature and reproductive following the terminal moult. Once they are adults, they inhabit a depth of about 240 metres. When a female snow crab spawns depends on its maturity. Females may spawn for the first time in September (these are called primiparous females) while the other females (called



PHOTO 1  
Kyoto trawling vessel (less than  
fifteen gross tons)

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PHOTO 2

Snow crab: female (top) and male

multiparous females) spawn in March. Male crabs mature a year earlier than females and complete only nine moults before being considered adults. However, they do not mate until they complete the terminal moult, which varies individually and can be anywhere between the eleventh and sixteenth moult. Paul (2000) gives more details on snow crab biology.

Snow crabs migrate between depths as they mature and also during the mating season. Males and females inhabit the same depth until the width of their carapaces reaches about 8 cm. After that, only male crabs move to water that is 260 metres or deeper. During the mating season, males and females come together at a depth of 220 to 290 metres and this most frequently occurs at around 270 metres (Yamasaki, 1994).

### 2.3 The snow crab fishery

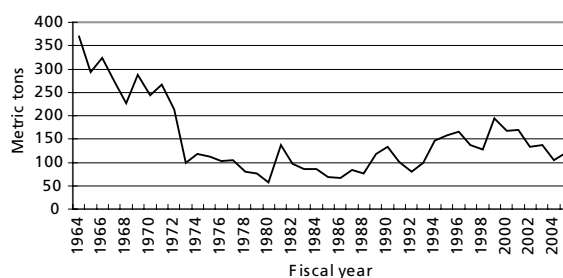
Snow crabs are harvested using bottom trawlers. In Kyoto, two classes of such trawlers, defined by gross tonnage (GT), operate. Small-scale trawlers, of less than 15 gross tonnes, predominate, comprising thirteen of the fifteen vessels. The other two vessels are of 20 GT and are hereafter referred to as offshore trawlers. Both classes of vessels fish offshore in waters 100 to 350 metres deep. The Kyoto Prefecture Fishery Coordinating Regulation sets the official season for bottom-trawler fishing as 1 September to 31 May.

Harvests of Kyoto's snow crab have followed a typical boom and bust cycle during the last few decades. The largest harvest volume of 369 t was recorded in 1964. Landings declined dramatically afterwards, to less than 100 t in the late 1970s and 58 t in 1980. Overfishing was said to be the cause of the decline. Various resource-recovery measures by the Kyoto Bottom Trawlers' Union were introduced beginning in 1983. Landings recovered to 195 t in 1999 (Figure 2). Currently, snow crab makes up about 30 percent by volume and 60–70 percent in value of the total catch from bottom trawling in Kyoto. In fiscal year 2005, snow crab production was 120 t with value at \$2.4 million (Figures 2 and 3).

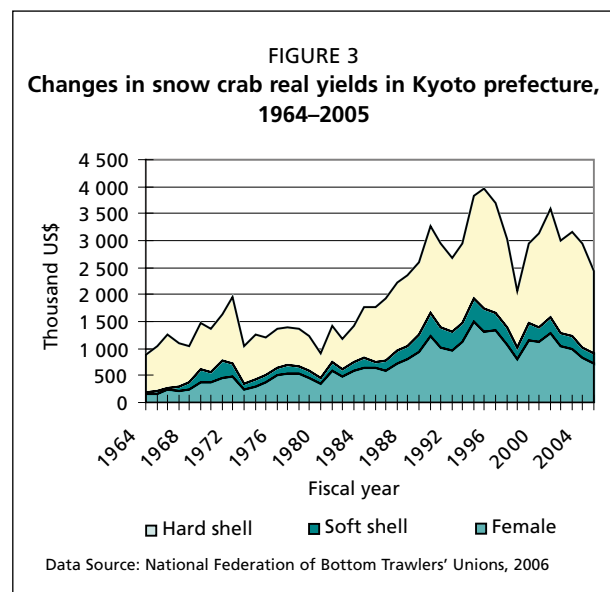
### 2.4 Markets for snow crab

Snow crab is classified into three commercial types: hard-shelled crab (males harvested more than a year after their last moult, which earn the highest price), soft-shelled crab (males harvested less than a year after the last moult, which earn the lowest price because the meat is soft and thin) and female crabs (which earn a medium price). The average price per kilogram in Kyoto's ex-vessel market in 2005 was \$61.65 for hard-shelled crab, \$5.60 for soft-shelled crab and \$11.40

FIGURE 2  
Snow crab landings in Kyoto prefecture, 1964–2005



Data Source: National Federation of Bottom Trawlers' Unions, 2006



for females (National Federation of Bottom Trawlers' Unions, 2006). Therefore, it is important, ecologically and economically, to preserve the female and young soft-shelled crabs and concentrate fishing efforts selectively on hard-shelled crabs. The efforts of the Kyoto Bottom Trawlers' Union to enhance stock levels and deter catches of female and soft-shelled crabs are discussed in Section 3.2.

### 3. REGULATORY HISTORY OF THE FISHERY

#### 3.1 Legal frameworks for bottom trawler fishing

The formal regulations for snow crab fishing in Kyoto have four components: (a) total fishing capacity (the number of vessels),

(b) length of the fishing season, (c) minimum sizes for crabs harvested and (d), limits on total harvest volumes. Total fishing capacity is managed and restricted by the Ministry of Agriculture, Forestry and Fisheries. The regulation is two-tiered for small-scale trawlers. First, the total number of licences granted nationwide to operate any trawler is prescribed and allocated to each prefecture by the ministry. If a licensed small-scale trawler owner decides to fish for snow crab, the owner must obtain a second permit from the ministry specifically for harvesting snow crab. Offshore trawlers, on the other hand, are simply licensed directly by the ministry.

The season for snow crab fishing is regulated by ministerial ordinances. Male snow crabs can be caught from 6 November to 20 March and the minimum carapace width allowed for harvest is 9 cm. Female snow crabs can be caught from 6 November to 20 January and are not limited by size.

The amount of snow crab that can be harvested is regulated by a total allowable catch (TAC) system that provides for the full utilization of the sustainable harvest and was implemented in 1997. The TAC for snow crab is administered both at the ministry (national) and at the prefectural level. For the 2006–07 season (from July to the following June), the national catch allowed was 7 113 t. Kyoto snow crab fishermen were allowed to tap two allocated TACs: the ministry allocation of 4 523 t to the entire western Sea of Japan region and the prefectural allocation of 130 t.

No fees are imposed on fishing licences that are issued by the government, either at the central or local level.

#### 3.2 Bottom trawlers' self-imposed measures

##### 3.2.1 Marine protected areas

In addition to the formal regulatory frameworks, a range of informal regulations has been implemented to protect snow crab resources and generate more value. The most important measure is the creation of marine protected areas (MPAs). The MPAs for snow crab in Kyoto consist of permanent marine reserves (no-take zones) and areas in which there are voluntary restraints on operations in spring and autumn.

The permanent marine reserves are intended to provide perpetual sanctuaries from fishing and henceforth called a "marine reserve". Since 1983, local trawler fishers have successively established six marine reserves within the snow crab's critical habitats, including its spawning grounds, based on scientific advice from the Kyoto Institute of Oceanic and Fishery Science, a prefectural research station (Yamasaki and Kuwahara, 1989; Yamasaki, 2002). Concrete blocks that are 3 m in length on each side have been sunk to the

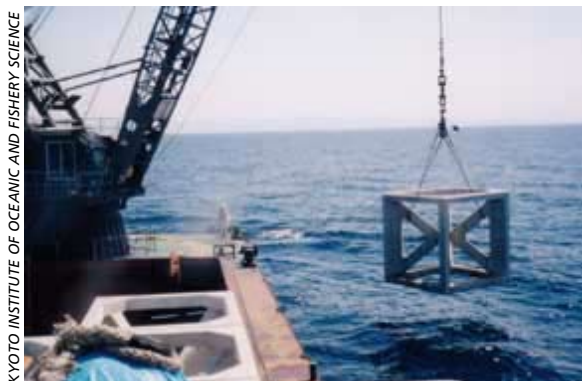


PHOTO 3  
Concrete blocks sunk in the  
marine reserves

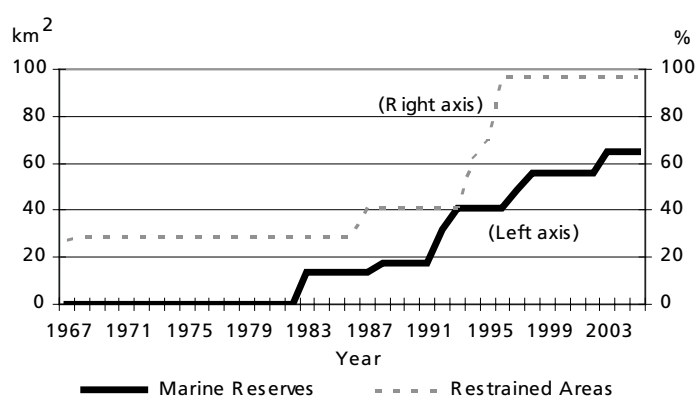


PHOTO 4  
Bycatch of snow crabs on a trawler's  
deck and targeted species in fish  
trays

bottom at a density of 3.8 blocks per km<sup>2</sup> (Photo 3) to ensure that trawlers are completely excluded from these areas. The cost of the blocks was paid by both the prefectural and the central governments. As of 2005, the total area of the marine reserves was 64.7 km<sup>2</sup>, which corresponds to about 19 percent of the snow crab fishing ground for Kyoto bottom trawlers (Figure 4). Also, construction began on an additional 3.1 km<sup>2</sup> in 2006.

The second type of MPA is a voluntary restraint on all trawler operations in certain areas, henceforth called a "restrained area". The fishing season for bottom trawlers is 1 September – 31 May, while snow crab fishing occurs only in winter months (from early November until the end of March). During the spring and autumn months, bottom trawler fishing targets other species, such as brown sole, deep-sea smelt and northern shrimp. However, since brown sole and snow crab share the same habitat, bycatch of snow crabs during fishing for brown sole is inevitable (Photo 4). These crab cannot be sold and must be released. The survival rate for the returned crabs is low, particularly for young and soft-shelled crabs. Yamasaki and Kuwahara (1991) estimate that about 45–60 percent of the initial snow crab stocks each year have been destroyed by this discarding required by the regulations. The only way to prevent the snow crabs from being harvested is to prohibit trawling for any kind of fish in those waters.

FIGURE 4  
Expansion of established MPAs off the coast of Kyoto



"Marine Reserves" indicate the total area (km<sup>2</sup>) of the no-take zones. "Restrained Areas" is the ratio (%) of the fishing-restrained area to the total snow crab fishing ground. Source: Marine reserve data from the Office of Fisheries of the Department of Agriculture, Forestry and Fisheries in Kyoto. Data on restrained areas generated by the author from agreements from the Kyoto Bottom Trawlers' Union.



TABLE 1  
Voluntary shortening of fishing seasons for snow crab

Class of crab	Formal fishing season based on Ministerial Ordinances	Voluntary Agreement
Hard-shelled crab	6 November through 20 March	Same
Soft-shelled crab	6 November through 20 March	11 January through 20 March
Female crab	6 November through 20 January	6 November through 10 January

Restrained areas are intended to prevent the bycatch of soft-shelled crab in spring and fall. Based on agreements among the bottom trawler operators, fishing within the snow crab's habitat (deeper than 200 metres) is restrained on a voluntary basis. Today, about 97 percent of the trawling ground is protected in spring and fall (Figure 4). The restraint is lifted when the snow crab season begins in winter.

The MPAs also generated some spillover effects. For example, the reduction of fishing pressure in the snow crab habitat during spring and autumn led to an increase in product quality, not only for the snow crab but also for other species living in those areas, including brown sole and deep-sea smelt. This increased the total profits of bottom trawler operators more than proportionally to total catch. This suggests that MPAs can provide a wide range of benefits that are not limited to the targeted species.

### 3.2.2 Other self-imposed measures

Several other measures have been implemented on a voluntary basis. Further reductions in the fishing seasons were agreed to for soft-shelled and female crabs (Table 1). A stricter minimum size (for soft-shelled crabs of 10 cm, above the 9 cm regulatory limit), was voluntarily adopted. The size of the trawl net mesh has been incrementally enlarged through agreement. Beginning in 2003, a new technology called the crab exclusion system was introduced to the nets to prevent the bycatch of snow crabs in spring and autumn. While dragging the trawl net, the crab bycatch is automatically passed out through the separator panel at the bottom of the net. This device helps to not only conserve snow crab resources, but also to increase the quality of targeted species by reducing bruises and scars caused by shells of crabs. Also, there is a self-imposed maximum catch limit per fishing trip. For example, catch limits per fishing day are 6 000 individuals for female crabs and 1 000 for soft-shelled crabs.

In recent years, snow crabs from Canada, Russia and North Korea have been sold in the market at much lower prices than domestically caught snow crab. As it is practically impossible for consumers to distinguish between the different sources, the influx of cheap imported snow crab has been a threat to Japanese fishermen. Japanese bottom trawlers responded by identifying their product in the market as domestically produced using a plastic tag. The tag for Japanese snow crab is now widely used by fishers and producers for crabs harvested from the western part of the Sea of Japan.

## 4. PROCESS OF DEVELOPING MPAS

Management of the snow crab fishery in Kyoto is typical of fisheries management in Japan, whereby the resource users make management decisions. The principal decision-maker for snow crab is the Kyoto Bottom Trawlers' Union. All of the bottom trawler operators in Kyoto belong to this union. Participation in this union has facilitated development of mutual trust among those involved over generations.

MPAs have generated positive results for Kyoto's snow crab fishery and for bottom trawler fishers in general, but a question remains: How did fishers come to an agreement to implement this measure? There are two primary answers to this question: a good choice of location at the beginning and an adaptive decision-making process.

When a local researcher first proposed the establishment of MPAs, many fishers strongly opposed the idea. Consequently, the locations first proposed for marine

reserves were waters in which the snow crab stocks were already heavily depleted. Among the proposed depleted areas, however, the prefectural research centre found one location that was biologically meaningful – a spawning area – and suggested in 1983 that it be the first MPA site, to which trawlers agreed. The economic impact for trawlers created by the first marine reserve was minimal. Its location turned out to be a good choice, since it was an area that was overfished but biologically important (Sanchirico and Wilen, 2001).

Under the adaptive decision-making process, MPAs were not implemented in their current scale in the beginning. Rather, marine reserves were first implemented on a small scale as an experiment and the bottom trawlers monitored their impact. This trial learning period lasted from 1983 until 1987. The voluntary restrained area followed a similar pattern – it was expanded only slightly in 1988 as part of the trial period. Once the effectiveness of the first marine reserve was recognized by the fishers, they played a proactive role in setting aside additional marine reserves and by abiding by the voluntary restrictions in spring and autumn. Both measures expanded dramatically after 1991 (Figure 4).

Self-governance activities in Kyoto fisheries can be viewed as a collaborative effort between local fishers and researchers. The Kyoto Institute of Oceanic and Fishery Science, which is the local research facility, has played a crucial role by providing information and guidance throughout the local bottom trawlers' decision-making process. For example, in selecting the size and location for each of the six reserves, bottom trawlers relied on scientific information provided by the institute. Development of the voluntary restraint areas occurred because research showed that regulatory discards in the spring and fall were decimating the crab stocks.

There are strong ties and trust between researchers and the bottom trawlers. In 2006, four experts at the Kyoto Institute of Oceanic and Fishery Science were engaged in trawler fishery research on snow crab and on other species, such as brown sole and northern shrimp. The results of their research are relayed to bottom trawler operators on a regular basis. Some researchers also conduct their work collaboratively on bottom trawlers so using industry vessels and gear.

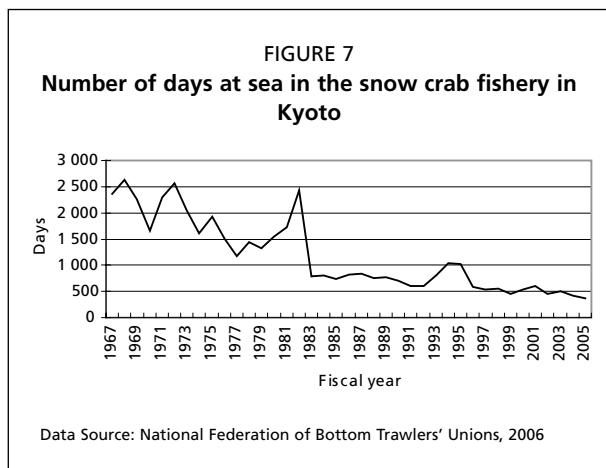
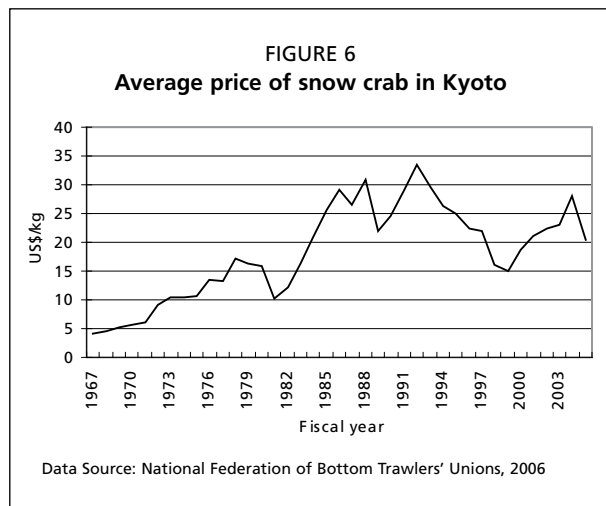
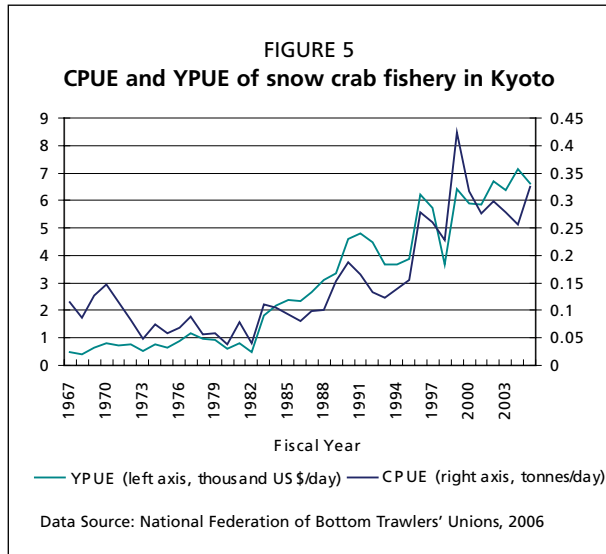
The local and central governments have assisted fishers in their activities via legal frameworks and financial support. For example, the official fishery systems, such as licences and permits, helped to identify stakeholders and enabled effective exclusion of outside fishing operators. Also, the government financed the concrete blocks sunk in the marine reserves.

Finally, government action on international coordination was necessary, because the same snow crab stock is harvested by Korea. During the fiscal years of 1997 and 1998, there was a serious territorial dispute between Kyoto and Korea, when Korean vessels entered Kyoto's offshore waters and set bottom gill nets for snow crab. This impeded Kyoto's bottom trawlers from operating (see the declines in landing and yield during this period in Figures 2 and 3, respectively). The central government was required to execute its role as the official authority in coordinating with neighbouring countries in such situations.

Although the local research station provided biological advice for management measures and government supported the process, trawler fishers themselves made the final management decisions. The fishers alone met repeatedly to discuss implementation of the MPAs – without government officers or researchers. They laid aside their differences and finally reached an agreement. Such participation by local fishers in the management process cuts down on transaction costs, particularly those associated with monitoring, enforcement and compliance (Makino and Matsuda, 2005).

## 5. EVALUATION OF KYOTO'S SELF-GOVERNANCE OF SNOW CRAB

Evidence of the economic benefits of self-governance in the Kyoto snow crab fishery are seen in catch per unit of effort (CPUE) and yield per unit of effort (YPUE) for 1967



to 2005 in Figure 5. The average CPUE for 1978 through 1982 was 54 kg/day; for 2001 through 2005, it had increased to 287 kg/day. Average YPUE for the same periods were \$758 a day and \$6 540 a day, respectively. The revenue per unit effort (RPUE) shows more improvement than the CPUE – an 8.6-fold increase in the RPUE compared to a 5.3-fold increase in the CPUE – which indicates that the quality of the catch has been enhanced. The corresponding rise in average price a kilo verifies this (Figure 6). According to an empirical analysis by Makino and Sakamoto (2001), the increase in the RPUE was attributed to a voluntary decrease in days fished (Figure 7) and the creation of MPAs.

The positive effects observed in Kyoto could be explained by a natural increase in snow crab stocks, rather than from the affect of MPAs. To examine this hypothesis, changes in real yields after 1983 in five neighbouring prefectures were compared (Figure 8). It is believed that snow crab trawlers in these five prefectures target the same stock or at least a closely related subgroup. One of the four prefectures has adopted management measures that mirror Kyoto's. Fukui's snow crab vessels operate off the coast of Kyoto, so it has been a partner in Kyoto's management of the snow crab fishery. Fukui also has its own MPA system. If natural fluctuations caused the recovery of the snow crab stocks, a similar trend should appear in all five prefectures. Figure 8 clearly shows that this was not the case. The real yield of snow crab in Kyoto and Fukui improved much more than yields in other prefectures. Thus there is strong evidence that the improvements in real yields of snow crab can be attributed to the management measures and MPAs implemented in the two prefectures.

## 6. DISCUSSION

One reason often cited for the value of fishery self-management has been the ability to use local users' experience with the resource. The

adaptive decision-making in the snow-crab fishery brought individual fishers into the process of choosing, examining and evaluating the effect of MPA sites. Their opinions were heard and their feedback was reflected in revised plans. This adaptive decision-making process by resource users reduced the risk of negative results from the MPAs and increased their legitimacy among users (Makino, 2004).

The snow crab case shows that a sense of legitimacy of management plans and regulations is important, especially in terms of compliance. Interviews of trawlers



operators suggest that they take pride in perfect compliance and that they believe that no one would violate rules that they create for themselves. Full compliance with the MPAs is achieved virtually without enforcement by the government. Further, this case shows that local resource users will autonomously expand and fine-tune management measures once they understand how effective they are.

There are several factors that are specific to Kyoto prefecture. The number of bottom trawling vessels in Kyoto is small (15) and the size of the vessels is nearly uniform. Such homogeneity among resource users would contribute to effective decision-making and implementation of the governance measures (Dietz and Ostrom, 2003). The roles played by government and other third parties also need to be emphasized. Scientific information provided by the research institute was a valuable resource that supported establishment and improvement of Kyoto's self-management regime. Financial support provided by local and central government also facilitated the construction of MPAs.

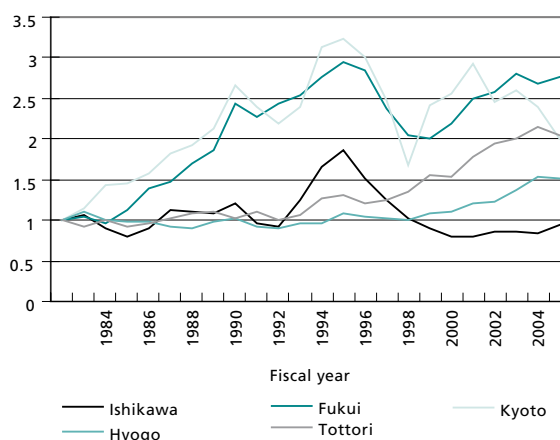
## 7. ACKNOWLEDGEMENTS

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FIGURE 8  
Changes in yields after 1983 in neighbouring prefectures



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